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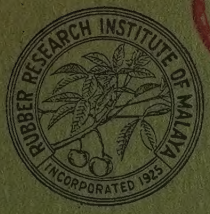

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THE APPLICATION OF LATEX TO HIGHWAY AND FLOOR SURFACING

BY

W. G. WREN

(London Advisory Committee for Rubber Research (Ceylon and Malaya))

Introduction and Summary

Research on the incorporation of rubber in roadway materials, having as its object the extension of the uses of rubber, was initiated in 1931 by the Board of the Rubber Research Institute of Malaya, who provided a separate grant for the purpose.

In the period 1931—1933 experiments in Malaya were made first with bituminous emulsions and latex; the conclusion was reached that these mixtures were unsatisfactory, and the experiments were discontinued. Attention was then directed to the preparation of a product which could be used as a resilient shock-absorbent material as a possible cheap substitute for rubber-capped paving blocks. Such a mixture was evolved early in 1933 and trial areas of this and other mixtures were laid on roads around Kuala Lumpur.

In 1933 the work came under the review of the Engledow Commission of Enquiry and in the report issued in July of the same year that Commission recommended (Section X B para 21 on page 25) "that the suitability of the existing research and trial work on rubber roadways be discussed with the London Advisory Committee as soon as possible."

The recommendation was accepted by the Board and the question of the location and nature of further work was investigated with the London Advisory Committee. The Board expressed the opinions that: (1) although the mixture evolved by the Rubber Research Institute of Malaya was probably the best of its kind so far prepared it was not entirely satisfactory as a rubber roadway material, and further investigations were necessary; (2) the R.R.I. product offered considerable possibilities for interior surfaces, but for road work it required to be subjected to heavier traffic than was available in Malaya; (3) it was necessary to design a satisfactory apparatus for mixing the ingredients of the latex composition; and (4) Malaya offered advantages for demonstration and experiment.

At this time research work on the incorporation of rubber in roadway materials was in progress in England, under the auspices of the Rubber Growers' Association, at the Imperial College of Science and Technology (where Professor Clements was concerned with mixtures of a type which had given promise in Malaya), at the Imperial Institute (where the London Advisory Committee Staff was investigating rubber-bitumen mixtures) and at the Chemical Research Laboratory, Teddington, (where Dr. Morgan was interested in the incorporation of rubber in tars).

Taking into consideration the views expressed by the Board as to the desirability of further investigations, that personal contacts would be possible not only with the organisations mentioned but with commercial organisations interested in this type of work and also the Building and Road Research Stations, and that practical experience had shown that considerable work on fundamental problems was necessary to preclude failure in technical trials, the London Advisory Committee and the Board agreed that the work could best be continued in Europe, and further work in Malaya postponed.

The Board further agreed to make a financial contribution for three years to defray the cost of the work, which was carried out at the Imperial Institute by Mr. Wren (transferred from Professor Clements' Staff at the Imperial College of Science and Technology) and two assistants in association with the Staff of the London Advisory Committee. On the expiration of the three years the Rubber Growers' Association assumed financial responsibility for the work.

The following paper by Mr. Wren summarises the work during the above period. It deals principally with the type of material which had given the most promise in Malaya viz. latex-cement mixtures. It includes an outline of: (1) microscopic investigations of these mixtures whereby information was obtained concerning the nature of the crystalline and amorphous products formed by the interaction of the cement and latex, and the manner in which these are dispersed in the matrix; (2) the effects of different stabilisers, which are essential to these mixtures, on the hydration of the cement, by means of the chemical determination of free and combined water; (3) the principles of compounding, whereby variation may be produced in the physical properties of the resultant products; (4) the type of apparatus most suitable for making these mixtures; (5) the description of physical tests evolved in association with the Building Research Stations, described in greater detail in a paper presented to the Institution of The Rubber Industry (Trans. I.R.I. Vol. 13 pp. 189—223); (6) the utilisation of these tests in order to make a comparison of the properties of latex-cement mixtures with other flooring materials; and finally a summary of other uses to which latex-cement materials may be put.

During the course of the work the opinion expressed by the Board that these products offer possibilities as flooring surfaces, rather than as roadway surfaces, was amply confirmed. Since the work commenced considerable commercial developments have taken place in these materials, and the fundamental knowledge obtained was placed freely at the disposal of any organisation interested.

Investigations on the development of latex mixtures for roadways were carried out in Malaya by Hastings during the period 1931 to 1933. (See R.R.I. Annual Report; 1932, p. 114; 1933, p. 136). Of the different mixtures tried, those containing aluminous cement gave the most promising results. Considerable progress of a practical character in working out the details of a suitable cement-latex mixture was then made, culminating in the laying in 1933 of an experimental section of road 4½ miles from Kuala Lumpur

on the Kuala Lumpur—Port Swettenham Road, where the traffic is fast and fairly heavy. In view of the promising results given by these experiments it was agreed that the subject should be studied further in London and that particular attention should be given to obtaining a better understanding of the fundamental principles involved in the preparation of latex mixtures for road and floor surfacing. As the economic factors are less exacting for flooring than for highways it was decided that the application of latex mixtures to flooring should receive prior attention. The main purpose of the investigation has now been fulfilled and this paper presents a summary of the work carried out and the results obtained.

Mixtures of aluminous cement and latex have been in use for some time both for flooring and other purposes; as early as 1923-4 patents were obtained for mixing cement with specially treated latex. The theory underlying this process is that the cement combines with the water of the latex and becomes hydrated —the latex losing its water and coagulating. How far this occurs in practice was not established at the outset of the work in London, and attempts were made to determine the extent of hydration of the cement and to examine the micro-structure of the mixtures. During the course of this work it became apparent that the structure and physical characteristics of the products were largely dependent upon the materials used in compounding and especially upon the latex stabiliser. A systematic study of the principles underlying the compounding of the mixtures was then undertaken and the relationship between compounding and physical properties determined. It thus became necessary to develop a series of tests to measure the physical properties, as no suitable methods were available. As a result of these experiments a number of cement-latex compositions were developed and the most suitable selected for small scale trials. A summary of the work carried out and the conclusions reached are given in the following sections:—

(1) Microscopic investigation
(2) Hydration of cement in aluminous cement-latex mixtures
(3) Principles of compounding
(4) Methods of mixing
(5) Relation of composition to physical characteristics
(6) Physical tests
(7) Comparison of cement-latex mixtures with other flooring materials
(8) Practical trials
(9) Application.

(1) Microscopic investigation

In the microscopic examination of cement-latex mixtures a study was made of the changes occurring when cement is mixed with latex; also, the product obtained after setting was examined.

In following the changes which occur when cement is mixed with latex it was found necessary to employ a very dilute latex (about 2 per cent dry-rubber-content) and to use finely ground cement in order to obtain layers sufficiently thin to permit of examination by transmitted light. When cement is mixed with water, hydration of the cement occurs and various crystalline products of hydration and deposits of amorphous material are formed; these may be recognised by their crystal habit and by staining reactions. When dilute latex was added to cement the crystal growth was found to be strongly inhibited but no conclusions could be drawn regarding the formation of amorphous deposits owing to the presence of latex particles making observation difficult but staining reactions indicated the presence of some hydration products. In the presence of latex containing alkalies, however, *e.g.* caustic potash, the crystal growth was greatly increased, the period required for crystal formation being much less than in the case of cement and water alone. Other materials, chiefly stabilisers of latex such as saponin, showed the reverse effect, crystal growth being greatly retarded.

In the examination of set cement-latex mixtures the usual methods of hand-sectioning by cutting or grinding were found to be unsuitable owing to the nature of the material; a heavy sledge microtome was useless as the hard cement grains spoiled the razor edge and grinding the material under liquid air was only partially successful owing to curving of the specimen as it thawed out. The method eventually used was to vulcanise the material by immersing it in molten sulphur (at 135°C. for about 20 hours) and then to grind the surface according to the practice employed in preparing rock sections. This method is open to the objection that a modification of the rubber phase must occur; the distribution of the mineral constituents, however, will probably not be changed.

The appearance of sections both by reflected and transmitted light, indicated the presence of incompletely hydrated cement grains embedded in a matrix of cement hydration products and rubber. With an increasing proportion of rubber the proportion of matrix increased. Mixtures containing alkaline materials, which were found to accelerate crystal growth, showed a more highly crystalline appearance and also clusters of amorphous material deposited at intervals in the matrix. Through the medium of staining reactions and an examination through crossed nicols these

clusters were shown to be aluminium hydroxide. Both with materials accelerating crystal growth and those retarding it, a fine grained structure was observed in the matrix, which was thought to be caused by the deposition of colloidal aluminium hydroxide upon the latex particles during coagulation.

(2) Hydration of cement in aluminous cement-latex mixtures

The microscopic examination of mixtures of cement and latex showed that the extent of the chemical reaction between aluminous cement and water is changed by the presence of latex and certain other materials. Experiments were carried out therefore to determine the effect of these materials on the combination of cement with water.

Specimens containing known proportions of cement, latex and the required material (chiefly latex stabilising agents) were prepared in small dishes and stored in a closed vessel at constant temperature. Determination of the combined water was made at intervals by removing a specimen, weighing and drying overnight to constant weight, care being taken to prevent oxidation of the rubber. Experiments were made with varying proportions of cement to rubber in the presence of such materials as saponin, casein, caustic potash and serum solids. It was found that the quantity of water chemically combined and that mechanically held depended upon the type of stabiliser added. After keeping for one month caustic potash mixtures contained 11 per cent combined water, in addition to 10.7 per cent water which could be driven off by heating at 105°C., whereas in a similar mixture containing saponin only 1.5 per cent water was combined and 4 per cent mechanically held. The serum substances in latex were found to decrease the rate of combination of cement and water but did not appear to reduce the amount of water finally combined.

(3) Principles of Compounding

It was apparent as a result of the work on microstructure and the hydration experiments that considerable differences might be anticipated in the properties of cement-latex mixtures prepared with various stabilisers and a systematic examination of the modifications produced by various stabilisers was undertaken. As a result of these experiments it was found that whilst the majority of stabilisers such as casein and saponin retarded the setting of the cement, a few materials such as caustic potash, gum arabic and triethanolamine accelerated it. The cement-latex compositions produced by these two types of stabiliser, respectively, were (1) a soft rubbery material containing a small proportion of combined

water and (2) a hard, cementitious product, containing a high proportion of combined water. The type of product obtained could thus be controlled by the stabiliser used in preparation.

For practical purposes it is necessary that cement-latex mixtures should remain in a stable or "workable" condition for a half to one hour, and that they should set hard within two or three days. Two tests were devised therefore to measure these properties, viz. a stability test which consisted in determining the period during which the mixture could be kept without coagulating when rubbed in a pestle and mortar for 15 seconds, and a setting test which consisted in observing the period which elapsed before attaining a certain arbitrary degree of hardness as measured by the indentation of a standard loaded needle.

By the aid of these tests it was a simple matter to evaluate the stabilising capacity of a number of substances and to control both the setting time and the hardness of the final product by adjusting the proportion of materials retarding and accelerating the cement set. The soft rubbery product obtained by reducing the proportion of the material accelerating the setting of the cement showed a tendency to crack owing to shrinkage caused by evaporation of water. This phenomena had previously been observed by Hastings (loc. cit.) and had been successfully overcome by incorporating sodium silicofluoride as a delayed coagulant; this material, however, has an acid reaction and so inhibits the hydration of the cement resulting in a long drying period, especially under conditions of a temperate climate. Attempts were made therefore to discover a delayed coagulant which had an alkaline reaction. A combination of calcium cyanamide and sodium metasilicate was found to be satisfactory for this purpose, the coagulation depending upon a slow removal of the stabilising agent (sodium metasilicate) and a subsequent liberation of calcium ions, which also accelerate the setting of the cement.

The relation between the time of the coagulation of the latex and the setting of the cement was found to be important in controlling the type of product obtained. If the latex remains stable during the setting of the cement the rubber particles tend to become surrounded by cement hydration products and do not readily form a continuous phase. On the other hand if the latex coagulates before the cement sets, there is a tendency for the cement particles to become coated with rubber which inhibits further hydration and setting. It is not particularly difficult, however, to obtain conditions in which the rubber coagulates during the hydration and setting of the cement so that an intimate mixture of cement hydration products and rubber is obtained.

When laying cement-latex compositions it is necessary to control the viscosity of the mixtures, in some instances a thin

cream being desirable and in others a stiffish paste. The addition of wood-flour or inert fillers was found to thicken the mixtures considerably; flocculation of the latex, by calcium chloride for instance, proved also to be a useful method. To reduce the viscosity, sodium silicate, caustic potash and most wetting agents, such as saponin, Igepon T were found very efficient. The action of these substances probably does not depend as much on changes in the viscosity of the latex as in the changes in the cement-water suspension.

The production of brightly coloured aluminous cement-latex mixtures is not an easy matter owing to the dark grey colour of the cement, but using a white filler and brightly tinted pigments pleasing colours can be obtained. Care has to be used in selecting the colours as many of them react with strong alkalis such as lime and caustic potash; satisfactory results have been obtained with "Fast-lime" colours.

Despite taking all reasonable precautions to standardise the ingredients and the conditions of mixing cement-latex compositions variation in stability, setting-time, viscosity and in the properties of the final product sometimes occurs. This was found to be due to variations in both the cement and the latex, neither of which can be reproduced exactly from batch to batch. These variations are a hindrance to the commercial development of the products and experiments are being carried out to determine the causes. The results obtained with many stabilising agents indicate that the resistance of latex to mechanical coagulation falls off considerably on storage, especially in the presence of strong alkalis; in one instance the stability was reduced to one fifth of its value after keeping for three days.

Nearly all cement-latex mixtures contain aggregates added either for cheapness, decorative purposes or in order to modify their properties. Most of the materials used as aggregates in cement and terrazo work have proved to be suitable for this purpose. Such materials as granulated cork, shredded waste rubber, wood chips, and asbestos fibre may be added to give pleasing decorative effects and to lower the cost but care must be taken to ensure that the aggregate is clean and that it is unlikely to react chemically with other constituents in the mixture. Experiments also shewed that it is necessary that the aggregate should be graded with regard to particle size in such a manner as to give a fair proportion of each size of particles ranging from the largest added to that of the coarsest cement grains. It was found that grading not only increased the strength of mixtures and reduced the proportion of binder required for a given aggregate but also assisted greatly in giving mixtures which were easily trowelled.

Experiments have been made replacing aluminous cement with Portland cement, attention being given chiefly to the white variety known as "Snowcrete." The products obtained by mixing "Snowcrete" and latex did not possess such good physical characteristics as those obtained with aluminous cement; either they shewed excessive shrinkage or they were hard and often tended to be friable with a rather low tensile strength. The difference in the nature of the products formed from Portland and aluminous cements is probably due to the different hydration processes involved in the two processes. With aluminous cement it has been shewn that colloidal aluminium hydroxide is produced, whereas with Portland cement crystalline calcium hydroxide is formed and it is obvious that a more intimate dispersion would be obtained with colloidal aluminium hydroxide in latex than with crystalline calcium hydroxide. Experiments are being made to prevent the formation of lime crystals in the hope of improving the cement-latex product obtained. An alternative is to provide a third substance which will give a good bond between lime and latex particles.

(4) Methods of mixing

The thicker mixtures, especially those containing aggregate, are conveniently mixed in a Werner-Pfleiderer machine. With mixtures of the consistency of thin cream a simple inverted T-shaped stirrer revolving at a speed sufficient to give a good vortex has been found satisfactory. It is of course necessary to add the stabiliser first when compounding the latex, otherwise flocculation or coagulation of the latex may follow. Generally it has been found convenient to mix the stabilising and vulcanising ingredients with the latex and the dry materials such as pigments and fillers with the cement. Care must be taken in selecting stabilisers and accelerators of the cement set so that interaction between them does not occur.

(5) Relation of the composition of mixtures to physical characteristics

It has been stated already that latex stabilisers and accelerators of the cement set exert a profound effect upon the properties of cement-latex mixtures. Marked differences are also brought about by varying the proportion of cement to rubber, varying the proportion of water and incorporating various filling materials. A brief account is given of the effect on the physical characteristics of the mixtures of (a) the rubber: cement ratio, (b) the water: cement ratio, (c) vulcanising ingredients, (d) various fillers and aggregates.

(a) *Effect of various proportions of cement and rubber*

Experiments have shown that with a higher proportion of cement to rubber than 100:20 a hard cementitious product is formed with little advantage over cement alone. The tensile strength of the mixtures was found to increase with increasing proportions of rubber, and the resistance to compression to decrease. The coefficient of restitution, a measure of the clasticity, increased with increasing proportions of rubber.

(b) *Effect of varying the proportion of water*

Specimens prepared with proportions of water increasing from 15 per cent to 35 per cent (reckoned on the cement) showed a progressive decrease in tensile strength. The observed values for resistance to compression were inclined to be irregular but there appeared to be an optimum proportion of water for each mixture. Determinations of the linear contraction on setting showed that increased proportions of water did not necessarily result in greater shrinkage; the greatest shrinkage was in some cases found in mixtures containing the lowest proportions of water. Thus a mixture containing 15 per cent of water showed a linear contraction of 4.4 per cent, whilst the same mixture with 25 per cent water showed only 1.8 per cent.

(c) *Effect of adding vulcanising ingredients*

Experiments undertaken to determine the effect of vulcanising ingredients showed that these had little effect on the mechanical properties of freshly prepared cement-latex mixtures. Accelerated ageing tests and natural ageing tests over a period of twelve months suggested, however, that with certain mixtures vulcanising ingredients gave better ageing properties.

(d) *Effect of fillers and aggregates*

It was found that 35 per cent of the cement in mixtures containing 100 parts of cement to 30 parts rubber could be replaced by inert fillers, such as limestone dust, without appreciably altering the resistance to compression. The replacement of this quantity of cement did not appreciably alter the tensile and compressive strengths of the softer mixtures but reductions in the strengths of the harder types were observed.

Ungraded aggregates such as marble chippings generally reduced the tensile strength of the product, whilst softer aggregates such as granulated cork produced a marked decrease in tensile and compressive strengths. The coefficient of restitution was also greatly influenced by the type of aggregate used;

granulated cork and shredded waste rubber gave products of high elasticity whereas marble and granite chippings had the opposite effect. The most satisfactory products generally were obtained when the physical characteristics of binder and aggregate were similar.

(6) Physical tests

Having prepared a number of cement-latex compositions, it was necessary to devise means whereby their physical characteristics could be compared. A series of physical tests were developed therefore which comprised the measurement of (a) tensile strength, (b) compressive strength, (c) hardness by indentation and recovery, (d) coefficient of restitution, (e) water absorption, (f) ageing, and (g) contraction during setting. Further tests still being developed include the measurement of the resistance to impact abrasion, adhesion, coefficient of friction, electrical and thermal conductivities, acoustic properties, fire resistance, ease of cleansing and effects of oils, fats, waxes and detergents. The development of these tests has necessitated devising in most cases a new test procedure; in the case of the compressive strength, tensile strength and coefficient of restitution tests new machines specially adapted for the purpose have been designed and constructed. All specimens were aged for at least one month before testing.

(a) *Tensile strength*

Tensile test determinations are carried out on a machine built in the laboratory workshops. The machine is of the simple-lever type resembling the Adie cement-tester; it is fitted with special grips and an electrically controlled device which enables the stretch of the specimen to be taken up.

Difficulty was experienced with tensile strength determinations owing to irregularities in the breaking load values. This has been overcome largely by adopting a carefully standardised method of preparation of the specimens and by using specially shaped test pieces. For hard mixtures the test piece is moulded in the form of a briquette as specified by the Argentine Government for cement testing; for soft rubbery mixtures a flat dumbbell piece held between wedge-action grips is used. Values for the breaking load can now be reproduced generally within limits of 15 per cent provided an average of at least 6 test pieces is taken for each determination.

As an alternative to the direct determination of tensile strength, transverse breaking tests have been attempted. Although they have the advantage of requiring neither special grips nor elaborate

shaped test-pieces it was found that the rubbery specimens could not be broken by this means as they easily bent and pulled through the supports. Transverse testing therefore has been discontinued.

(b) *Compression tests*

A machine suitable for compression testing also has been built in the workshops. This machine has the advantage that an autographic record is obtained showing the stress-strain relationship when a small cylindrical specimen 2 inches diameter and $1\frac{1}{2}$ inches in height is subjected to compression. It has been shown that two distinct types of stress-strain curve can be obtained with cement-latex mixtures, one resembling that of cement, the other resembling highly compounded rubber. A third type combining both these characteristics is thought to represent one of the most satisfactory types of mixture. The results obtained are readily reproducible.

(c) *Hardness*

In order to determine the resistance to indentation the specimens are supported in a surrounding ring of concrete and the middle of the specimen is subjected to a load of 1,000 pounds per square inch for one minute, the load being transmitted to the specimen by means of a circular plunger. The indentation under load and the permanent deformation are recorded.

(d) *Coefficient of restitution*

It was found that the apparatus commonly used for measuring the coefficient of restitution (the sclerometer) was unsuitable for many cement-latex compositions owing to the non-homogeneous nature of the material. Satisfactory tests were carried out however using a large pendulum, the bob of which consists of a steel sphere $2\frac{1}{4}$ inches in diameter; this is allowed to fall from a standard position and to rebound from the surface of the specimen. The height of rebound is estimated from the time required for the bob to come to rest against the specimen, an electrical device indicating this position.

(e) *Water absorption*

Water absorption is measured as the percentage increase in weight of a cleaned specimen suspended in distilled water for a given time at room temperature.

(f) *Ageing*

Two types of ageing test are carried out, (i) accelerated ageing, by storing the specimens for a number of days at 100°C., (ii) natural

ageing by storing specimens for a period of twelve months, some being exposed to outside atmospheric conditions, others being stored indoors. Measurements are made of the changes in tensile and compressive strength.

(g) *Contraction*

An apparatus has been constructed for measuring volume shrinkage of cement-latex specimens during setting and hardening. Some determinations have been made with this apparatus but the majority of the results obtained were direct measurements of linear contraction taken on tensile test-pieces.

(7) Comparison of cement-latex mixtures with other flooring materials

A number of cement-latex compositions now commercially available for flooring have to compete with established flooring materials and it was considered that it would be of interest to compare the properties of these materials, prepared either commercially or in the London Advisory Committee laboratories, with other types of flooring materials such as mastic asphalt, concrete, magnesite, deal and oak. All the materials tested were subjected to compression, tensile, indentation, coefficient of restitution and water-absorption tests using identical conditions as far as possible.

It was found that the compressive strength of cement-latex mixtures varied over a fairly wide range, certain of the mixtures being more easily crushed than deal, others being more difficult to crush than oak but none had the compressive strength of concrete or magnesite.

Tensile strength determinations showed that cement-latex mixtures have a strength similar to mastic asphalt, rather less than that of magnesite or concrete material and much less than that of wood. Indentation tests indicated an exceptionally wide "hardness" range—the results showing values varying from those of hard magnesite flooring to those of materials softer than any of the non-rubber compounds examined. Recovery after indentation showed that cement-latex mixtures are similar to wood, asphalt and magnesite. Measurements of the coefficient of restitution demonstrated the rubbery nature of cement-latex compositions, some of the materials showing a resiliency greater than that of any of the other materials tested. Water absorption experiments indicated that cement-latex mixtures do not absorb as much water as some of the other materials examined, for example wood; on the other hand they are not as resistant to water as mastic asphalt, which of course is highly impervious. Magnesite absorbed con-

siderably more water than the majority of the cement-latex mixtures, which in some cases were superior even to concrete.

The results of these comparative tests showed that commercial cement-latex mixtures possess physical properties similar to those of other flooring materials but they have the important advantage that their resilience can be increased to a value exceeding that of any other non-rubber flooring material. The range in properties of the mixtures is very wide and by making small adjustments in composition it is possible to obtain material nearly as hard as cement or softer than asphalt. The mixtures possess many valuable properties not indicated by these experiments; they appear to give an excellent non-skid surface which when wet is retained to a high degree. They have good heat-insulating and sound-deadening properties, they are resistant to oil and chemicals, and, unlike magnesite, they do not corrode metals.

(8) Practical Trials

Although laboratory tests give a useful indication of the relative merits of a series of mixtures as flooring materials, it is obvious that the only reliable method of estimating the value of a given mixture is by means of a service test. A number of trials have been carried out therefore by laying the mixtures under conditions where heavy traffic is encountered, observations being made on (a) the ease and suitability of laying, (b) the finished appearance and wearing properties.

Two series of mixtures have been laid, one incorporating a fairly hard binder, the other a soft rubbery binder; in all cases aggregate such as marble chippings, granite chippings, sand, asbestos, cork, and shredded waste rubber has been added. A Werner-Pfleiderer mixer was employed for the preparation of most of the mixings, patches of about 20 to 25 pounds of material being mixed and laid by trowelling, the most efficient method found being to lay the mixture a little at a time and not to spread a whole batch over the floor surface at once. Some of the mixtures were finished by hand, the surface being trowelled smooth as when laying concrete; others were allowed to harden and the surface then buffed with a sanding machine, exposing aggregate in section and thus introducing a terrazo effect.

The following trials have been made:—

(1) Three flights of stone steps receiving a fair amount of traffic were refaced with the hard cement-latex mixture containing granite, marble and shredded waste rubber as aggregate respectively. Each flight of steps is wearing satisfactorily, one having been laid for two years, the others for about eighteen months.

(2) Various floor surfaces, some of wood and some of stone, have been covered with different mixtures and both the rubbery and hard types of mixtures appear to be satisfactory after a year's wear. A surface exposed to all weather conditions was divided into two portions, one portion was covered with a material containing vulcanising ingredients the other with the same material without vulcanising ingredients; after six months both surfaces appear to be equally satisfactory with no apparent differences.

(3) A section of the laboratory floor was laid with a rubbery mixture containing shredded waste rubber. This was not successful owing to poor adhesion at the joints where one batch was finished and the next one started.

(4) A piggery at the Hertfordshire Farm Institute, St. Albans, was laid in two sections with a hard mixture, one containing granite chippings, the other shredded waste rubber. The piggery was laid about twelve months ago and is satisfactory except for a portion where the pigs have "rooted" out some of the waste rubber aggregate.

(9) Applications

The potentialities of these cement-latex mixtures are now becoming more generally recognised commercially. Not only are they being used as flooring materials in public buildings, offices and workshops and in shipbuilding, but they are also being utilised for water-proofing walls, as linings for tanks which have to hold corrosive liquids, as pipe-jointing material, for surfacing tennis courts and in the construction of pedestrian crossings. Other possibilities include their use for cementing glass to other materials, as an adhesive for mounting tiles and as a resilient covering for rollers used in the spinning of flax and similar materials. These applications have been discussed with the appropriate commercial organisations.

A paper was read before the Institution of the Rubber Industry (Trans I.R.I., Vol. 13 p. 189,) giving in greater detail the results of the work outlined in this paper and a patent (B.P. 484,712) was obtained in May 1937 protecting certain methods of compounding these materials.

During the course of the work a considerable number of enquiries regarding cement-latex mixtures have been dealt with and advice has been given on the procedure of preparing and laying the mixtures. Contact has been maintained with commercial firms interested in these materials, with the Building Research Station, Watford, and with the Highways Department, Imperial

College of Science and Technology, from whom many helpful suggestions have been received during the course of the work.

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Botanist	E. R. Guest, B.Sc. (Lond.), A.R.C.S., A.I.C.T.A.
Botanist	E. D. C. Baptist, Ph.D. (Lond.), M.Sc., A.R.C.S., D.I.C. (on leave)
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Asst. Botanist	K. N. Kaimal, B.A. (Madras)
Asst. Botanist	T. V. Vaidyanathan, B. Agric. (Bombay)

Chemical Division

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Soils Chemist	A. W. J. Dyck, Ph.D. (McGill), M.A. (Sask.)
Asst. Soils Chemist	K. S. Pillay, B.A. (Madras), F.C.S.

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